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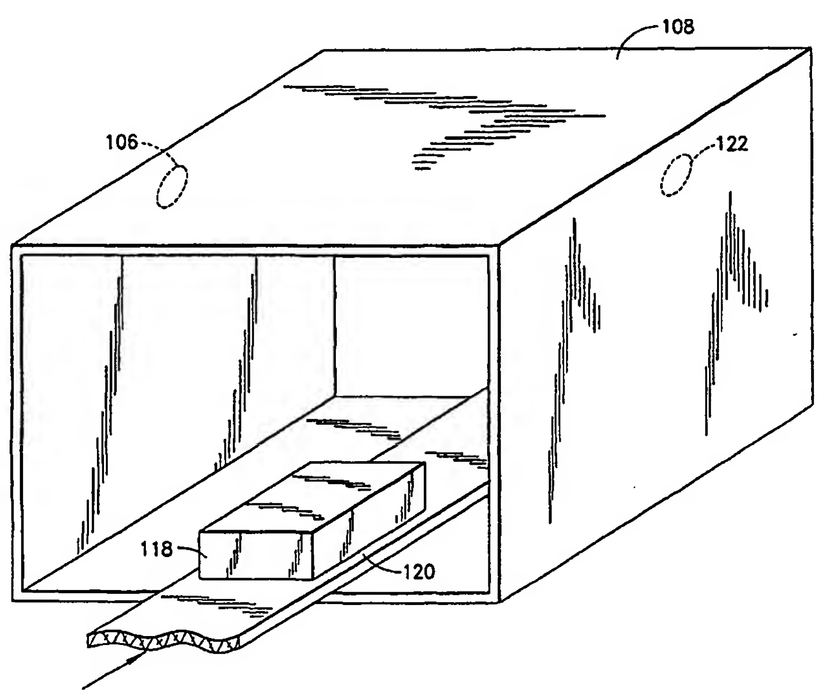
(57) Abstract

An RF base station system includes an RF signal generator coupled to an RF emitter (106, 122), such as an antenna and an RF-reflective surface or field shaper (108) arranged to reflect RF signals emanating from the RF emitter to increase the effective tag reading volume of the base station system. In an illustrative embodiment, a plurality of reflective surfaces may be arranged to form the walls of a tunnel-like enclosure (108) to confine RF energy from the RF emitter (106, 122) to a tag-reading volume within the enclosure. In addition to confining the RF energy, the geometry of the reflective surfaces, the carrier frequency of the RF signal, and placement of the RF emitter (106, 122) may be chosen so that the probability is increased that the RF field strength within the enclosure (108), or a portion thereof, meets an RF tag's reading threshold requirement. In particular, the enclosure geometry, the carrier frequency of the RF signal, and placement of the RF emitter (106, 122) may be chosen so that multiple RF propagation modes are established within the cavity formed by the enclosure.



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COMMUNICATING WITH RADIO FREQUENCY IDENTIFICATION TAGS WITHIN SHAPED ELECTROMAGNETIC FIELDS

FIELD OF THE INVENTION

The invention relates to radio frequency identification (RFID) systems and, more particularly, to RFID transponders (tags) which employ RF reflective materials to produce a region of RF field strength that enhances the operation of an RFID system.

BACKGROUND OF THE INVENTION

Radio Frequency Identification (RFID) transponders (tags) are operated in conjunction with RFID base stations for a variety of inventory control, security and other purposes. Typically an item having a tag associated with it, for example, a container with a tag placed inside it, is brought into a "read zone" established by the base station. The RFID base station generates a continuous wave electromagnetic disturbance at a carrier frequency. This disturbance is modulated to correspond to data that is to be communicated via the disturbance. The modulated disturbance, which carries information and is sometimes referred to as a signal, communicates this information at a rate, the data rate, which is lower than the carrier frequency. The transmitted disturbance will be referred to hereinafter as a signal or field. The RFID base station transmits an interrogating RF signal which is modulated by a receiving tag in order to impart information stored within the tag to the signal. The receiving tag then transmits the modulated, answering, RF signal to the base station.

RFID tags may be active, containing their own RF transmitter, or passive, having no transmitter. Passive tags, i.e., tags that rely upon modulated back-scattering to provide a return link to an interrogating base station, may include their own power emitter, such as a battery, or they may be "field–powered", whereby they obtain their operating power by rectifying an interrogating RF signal from a base station. Although both types of tag have minimum RF field

strength read requirements, or read thresholds in general, a field-powered passive system requires at least an order of magnitude more power in the interrogating signal than a system that employs tags having their own power sources. Because the interrogating signal must provide power to a field-powered passive tag, the read threshold for a field-powered passive tag is typically substantially higher than for an active tag. However, because field-powered passive tags do not include their own power source, they may be substantially less expensive than active tags and because they have no battery to "run down", field-powered passive tags may be more reliable in the long term than active tags. And, finally, because they do not include a battery, field-powered passive tags are typically much more "environmentally-friendly".

Although field-powered passive tag RFID systems provide cost, reliability, and environmental benefits, there are obstacles to the efficient operation of field-powered passive tag RFID systems. In particular, it is often difficult to deliver sufficient power from a base station to a field-powered passive tag via an interrogating signal. The amount of power a base station may impart to a signal is limited by a number of factors, not the least of which is regulation by the Federal Communication Commission (FCC). In addition to limits placed upon the base station's transmitted power, i.e., the power level at the base station's antenna input, RFID tags are often affixed to the surface of or placed within, a container composed of RF absorptive material. The container may move along a conveyor or roller system and, as the container enters the reading zone of a reading station, an interrogating signal is transmitted to the container. Ideally, the tag would be read regardless of the tag's location within the container or the orientation of the container as it passes the reading station. Unfortunately, the electromagnetic field pattern set up by an RF signal will typically include areas of relatively low field strength which preclude the reading of RF tags as they pass by a reading station. In the case of such a reading failure, a human operator may have to intervene by re-orienting the container and passing it by the read station once more. Alternatively, human operators may be required to orient containers in a preferred orientation so that the containers may be reliably

read as they pass the reading station. Such human intervention can be a costly, time consuming, and relatively unreliable approach.

There is, therefore, a need for a RFID system that provides reliable, cost effective, reading of RF tags which may be introduced into a reading area in a variety of orientations and which may be affixed to the surface of or placed at a variety of locations within the containers.

Related applications and issued patents

Related U.S. Patents assigned to the assignee of the present invention include: 5,528,222; 5,550,547; 5,552,778; 5,554,974; 5,538,803; 5,563,583; 5,565,847; 5,606,323; 5,521,601; 5,635,693; 5,673,037; 5,682,143; 5,680,106; 5,729,201; 5,729,697; 5,736,929; 5,739,754; 5,767,789; 5,821,859; and 5,912,632. Patent applications assigned to the assignee of the present invention include: Application No. 08/621,784, filed on March 25, 1996 entitled, "Thin Radio Frequency Transponder with Leadframe Antenna Structure" by Brady et al., now U.S. Patent 5,786,626; Application No. 08/626,820, Filed: 4/3/96, entitled, "Method of Transporting RF Power to Energize Radio Frequency Transponders", by Heinrich et al., now U.S. Patent 5,850,181; Application No. 08/694,606 filed 8/9/96 entitled, "RFID System with Write Broadcast Capability" by Heinrich et al. ; Application No. 08/681,741, filed 07/29/96 entitled, "RFID Transponder with Electronic Circuit Enabling and Disabling Capability", by Heinrich et al., now U.S. Patent 5,874,902; PCT International Application No. PCT/EP95/03903 filed 20 September 1995; PCT International application published as Publication Number WO96/13793 published 9 May 1996; and PCT International Application No. PCT/US98/23121 filed 30 October 1998 (Docket No. DN38386 PCT). The above identified patents and patent applications are hereby incorporated by reference.

SUMMARY

An RF base station system in accordance with the principles of the invention includes an RF signal generator coupled to an RF emitter, such as an antenna. One or more RF-reflective surfaces are formed and arranged to reflect or shape RF fields emanating from the RF emitter to increase the effective tag reading volume of the base station system or to shape the field. In general the system includes at least one active RF emitter, such as an antenna, and one passive RF emitter, such as an RF reflector.

In an illustrative embodiment, a plurality of reflective surfaces may be arranged to form the walls of a tunnel-like enclosure to confine RF energy from the RF emitter to a tag-reading volume within the enclosure. In addition to confining the RF energy, the geometry of the reflective surfaces, the carrier frequency of the RF signal, and placement of the RF emitter may be chosen so that the probability that the RF field strength within the enclosure, or a portion thereof, meets an RF tag's reading threshold requirement. In particular, the enclosure geometry, the carrier frequency of the RF signal, and placement of the RF emitter may be chosen so that multiple RF propagation modes are established within the cavity formed by the enclosure. Additionally, the reflective surfaces, referred to herein as a "field shaper", establishes multiple propagation modes within the base station's tag read zone, thereby substantially increasing the proportion of the read zone volume within which the electromagnetic field established by the interrogating RF signal meets or exceeds the read threshold of the RF tags.

In accordance with the principles of the invention, the dimensions of the enclosure are determined by a number of design criteria. In an illustrative embodiment, the enclosure is formed into a tunnel of four reflective surfaces with at least one dimension of the tunnel at least twice the wavelength of the base station's interrogating signal. This ensures that multiple propagation modes will be established within the cavity and, as a result, the RF energy of an interrogating signal will be more evenly spread, with the node of one mode at least partially superimposed upon the antinode of another mode.

In other illustrative embodiments, one or more active emitters, such as antennas, and one or more passive emitters, such as reflectors, may be arranged to shape the read zone in a manner which thereby produces a read zone having a preferred geometry. Or, the emitters may be arranged so that the field from one emitter does not interfere with the field of another.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and further features, aspects, and advantages of the invention will be apparent to those skilled in the art from the following detailed description, taken together with the accompanying drawings in which:

Figure 1 is a conceptual block diagram of an RFID system in accordance with the principles of the invention;

Figure 2 is a perspective view of an illustrative rectilinear tunnel embodiment of an RFID system in accordance with the principles of the invention;

Figures 3A and 3B are landscape views of the illustrative tunnel embodiment of Figure 2;

Figure 4 is a landscape view of the illustrative tunnel embodiment of Figure 2, with the addition of a tunnel aperture cover; and

Figures 5A and 5B are landscape views of partially enclosed embodiments of an RFID system in accordance with the principles of the new field shaping reading system.

DETAILED DESCRIPTION

An RFID system in accordance with the principles of the present invention is illustrated in the conceptual block diagram of Fig. 1. An RF base station 100 includes an RF transmitter 102, an RF receiver 104, and an RF emitter 106. Illustratively, the emitter is an antenna 106 connected to the transmitter 102 and receiver 104. The new base station 100 also includes an RF field shaping element, or field shaper, 108. An RF tag 116 such as may be used in

conjunction with the base station 100 includes an RF front end 110, a signal processing section 112, and an antenna 114.

In operation, the base station 100 interrogates the tag 116 by generating an RF signal having a carrier frequency F_c. The carrier frequency F_c is chosen based on a number of factors known in the art, including the amount power permitted at that frequency by FCC regulations. The RF signal is coupled to the antenna 106 and transmitted to the tag 116. As will be discussed in greater detail below, the tag may be affixed to the surface of a container, located on an automobile windshield, or packed within a container, for example. The container associated with the tag 116 typically is moved into a "read zone," that is, a volume within which it is intended that the RF tag will be successfully interrogated. The read zone, which, for some embodiments, will also be referred to herein as the effective tag read volume, is primarily defined by the base station antenna 106 and the field shaper 108 as well as the tags. The tag 116 may be in any of several orientations with respect to the base station antenna 106 as the tag 116 is brought into the read zone.

The RF field established by the antenna, or emitter 106, will, ostensibly, be received by the tag antenna 114 and, if the RF signal's field strength meets a read threshold requirement, the RF tag will respond to the reception of the signal by modulating the RF carrier to impart information about the associated container onto the back-scattered RF field which propagates to the base station 100. The RF signal transmitted by the base station 100 must have sufficient field strength, taking into account the polarization of the signal and of the tag's antenna, at the location of the tag 116 for the tag to detect the RF signal. In the case of a field-powered passive tag, the interrogating signal's field strength generally must be great enough for the tag 116 to rectify the signal and use the signal's energy for the tag's power source.

For a variety of reasons, the direct path field strength of the interrogating RF signal may not reach the read threshold level of the tag 116 at the tag's location. For example, the field pattern set up by the antenna 106 may have a null at the tag's location. The null may be due to an antenna pattern, nearby

objects, etc. Furthermore, even though the tag is moved through the read zone, it may never encounter an area where the direct path field strength from the antenna 106 meets the read threshold requirement. The field shaper 108 comprises one or more reflective surfaces arranged to shape the field pattern of the interrogating RF signal emitted by the antenna 106 to enhance the operation of the base station within the read zone.. That is, as will be explained in greater detail below, the field shaper 108 acts as an RF emitter by reflecting the RF energy of an interrogating RF signal. The RF energy may be reflected in such a manner as to increase the effective tag reading volume within the read zone by decreasing the percentage of the read zone which does not have sufficient field strength supplied by the interrogating signal. The RF energy may also be reflected in a manner that shapes or confines the RF energy in order to improve the probability of reading a tag within the read zone. The field shaper thereby increases the effective tag reading volume, i.e., the volume in which the tag may be reliably read. The concept of effective reading volume takes into account the prescribed read volume and "holes" within the prescribed read volume created by nulls in the electromagnetic field within the prescribed read volume.

The field shaper 108 may have any of a variety of shapes, but its size, shape and distance from and orientation to the antenna 106 may be tailored to the requirements of a specific application. That is, a variety of design parameters, such as the base station carrier frequency F_c, the size and "lossiness" of packaging materials, and the room available for the base station, are typically predetermined. These and other factors such as RF power density are taken into account when determining the size, shape, and orientation of the field shaper 108 in accordance with the principles of the invention to establish an RF field pattern within the base station read zone with a higher effective reading volume. That is, the field shaper 108 operates to create a read zone having a higher percentage of its volume suffused with an RF signal having sufficient field strength to meet an RF tag's read threshold requirement. In effect, the field shaper 108 may be employed to form at least a partial resonant cavity. Commercially available electromagnetic simulation packages, such as

HFSS and IE3D available from Hewlett-Packard Corporation, Palo Alto, California, and Zeland Software may be employed to optimize the specific geometries of an RFID system in accordance with the principles of the invention by determining the shape, the size, the location and orientation of the field shaper 108 relative to the antenna 106, and to thereby at least partially superimpose the node of one propagation mode within the cavity over an antinode of another propagation mode within the cavity.

This field shaping may be effected spatially, temporally, or in both manners. That is, the number and/or size of the aforementioned "read holes", that is, volumes of insufficient field strength within the read zone, may be reduced in order to increase the effective reading volume. Additionally, the location of the read holes may be rapidly swept through the read zone. The utility of this temporal modification of read holes lies in the fact that passive RF tags typically must have their power source refreshed at a minimum threshold rate. This minimum threshold rate is related to the power dissipation of the tag's electronics and the capacitance of the tag's storage capacitance. Since the storage capacitance is generally held to a minimum in order to reduce the volume and expense of the tag, the minimum threshold rate is related to a minimum data packet size, which might, in turn, depend upon the data encoding and other factors. The temporal modification of read holes may be accomplished by moving the tag relative to an interrogating RF emitter, e.g., moving the tag along a conveyor or moving the RF emitter. Temporal modification of the read zones may also be effected by changing the carrier frequency of the interrogating RF signal. In the latter case, in order to reduce out of band signals, carrier frequencies are generally switched gradually, over a prescribed time period.

The perspective drawing of Fig. 2 shows an illustrative embodiment of the RFID base station system of Fig. 1 in which like components have like designation numbers. In this illustrative embodiment, the package 118 contains an RFID tag 116 (not shown) and moves along a conveyor 120 into a field shaper 108 illustratively formed into the shape of a generally rectilinear tunnel.

The conveyor 120 may be a conveyor belt, a roller system, or other conveyor mechanism.

The field shaper 108 may be composed of any of a variety of materials, with the interior surface of at least one of the four panels which make up the "tunnel" composed of a material which reflects RF energy at the interrogating signal's carrier frequency. The tunnel could be composed of a wire mesh, the openings of which are no greater than one-tenth the wavelength of the interrogating signal, for example. Or, the tunnel could be composed of solid metal sheets, or a relatively inexpensive structural material could supply whatever support and rigidity is required for the tunnel, with a reflective material sprayed or otherwise coated on the surface of the structural material. In the illustrative embodiment of Fig. 2, the antenna 106 is located at the top inside of one of the tunnel sides as diagrammatically indicated and connected in conventional fashion to the base station RF transmitter 102 and receiver 104 (not shown). One or more additional emitters 122 such as diagrammatically indicated in Fig. 2 may be situated within the tunnel to provide further assurance that a passing tag 116 will be read within the read zone, defined, in this illustrative embodiment, by the perimeter of the tunnel 108. Any of the emitters may be moved along a track mount (not shown) or rotated about a pivot mount (not shown) to alter the location and/or angle at which the emitter transmits the interrogating signal into the tunnel 108. Slits or other openings may be formed in any of the four sides (left, right, top and bottom) of the tunnel and partially or completely open sides are contemplated by the invention.

Figure 3A provides a portrait view down the length of a tunnel 108, illustrating the relative position of the emitter 106, container 118, conveyor 120, and optional second emitter 122 in greater detail. In this illustrative embodiment, the emitter 106, and emitter 122 are circularly polarized, low axial ratio antennas such as may be obtained from Cushcraft Inc., Manchester, New Hampshire, for example. Elliptically polarized antennas having any of a number of axial ratios which, therefore, yield anything from linear to circular polarization, may be employed. The interrogating signal may be transmitted alternately between the

antennas 106 and 122, or may be supplied continuously, with the maximum permissible power divided between the antennas. The interior surfaces of the tunnel 108 will be referred to hereinafter, for the sake of convenience, as top 124, bottom 126, left side 128 and right side 130. The left and right sides are of a height H and the top and bottom have a width W associated with them. Although having any one of the surfaces reflective will enhance the operation of the RFID system, the top 124 and two side surfaces 128 and 130 are preferably composed of an inexpensive RF reflecting material such as a wire mesh. Additionally, the tunnel geometry is chosen to establish multiple waveguide modes within the enclosure. That is, the dimensions of the enclosure are chosen not to be so small, i.e., with all the sides only a fraction of a wavelength, so that, single mode propagation, with its attendant nulls or "holes" within the read zone, may be established within the cavity.

Figure 3B provides a side view of the illustrative tunnel embodiment of Figure 3A, with like elements having like designation numbers. The tunnel is of a length L. Although the emitters 106 and 122 are located generally midway along this length, the emitters are, as illustrated, slightly offset from one another. The field shaper 108 may be in a variety of shapes, but its size, shape and distance from an orientation to the antenna 106 will be determined by the requirements of the specific application. A variety of design parameters, such as base station carrier frequency F_c, the size and "lossiness" of packaging materials, and the room available for the base station, are typically predetermined. These and other factors are taken into account when determining size, shape, and orientation of the field shaper 108 in accordance with the principles of the invention to establish an RF field pattern within the base station read zone with a higher effective reading volume.

In the illustrative tunnel embodiment, the field shaper 108 operates to some degree as an RF cavity and the dimensions of the cavity are chosen to increase the quality factor, or "Q", of the cavity, thereby creating a zone within the cavity with higher field intensity and diverse polarizations. Not only is the Q of the cavity enhanced by the reflective surfaces within the tunnel 108, multiple

transmission modes are established within the tunnel 108. By improving the Q, the new RFID system establishes a read zone within the tunnel which confines energy that would otherwise immediately propagate away from the read zone, thus enhancing the probability that a tag within the read zone will be exposed to an RF field that is greater than or equal to the tag's read threshold requirement. Furthermore, by supporting multiple transmission modes within the tunnel, the new RFID system distributes the RF energy more evenly throughout the tunnel 108, thereby further increasing the probability that an RF tag within the read zone will be exposed to an RF field that meets or exceeds the tag's read threshold requirement. That is, unlike single mode propagation, multimode propagation establishes a distribution of nodes and anti-nodes throughout the tunnel, thereby distributing the RF energy much more evenly than it would be, for example, with single mode propagation and, consequently, increasing the probability that an RF tag anywhere within the tunnel will be properly read. Quality factor, single mode propagation, and multi-mode propagation within a cavity are all known in the art and are discussed, for example, by William H. Hayt, Jr. in Engineering Electromagnetics, Mcgraw Hill, Third Edition,1974 pages 443-462, and by John D. Kraus and Keith R. Carver, in Electromagnetics, McGraw Hill, Second Edition, 1973, pages 583-590. As is known in the art, the quality factor of the tunnel enclosure will vary depending upon the lossiness of material inserted into the tunnel 108. That is, for example, if the RF tags to be read are packaged with blue jeans, water bottles or other particularly lossy materials, the quality factor of the tunnel will be adversely affected. If, for whatever reason, the RF transmitter is not typically operated at peak power, the power introduced to the antenna 106 may be increased to the maximum power permitted by FCC regulations to overcome the adverse effects on the enclosure's quality factor. Currently, for example, those regulations limit the power input to an antenna to one Watt at a carrier frequency of 2.45 gigahertz (GHz).

In the illustrative embodiment of Figures 3A and 3B, the dimensions of the tunnel 108 are chosen to resolve two competing design criteria. That is, the

field shaper 108 should be located relatively close to the emitter 106 in order to reflect sufficient energy into the tag read zone. At the same time, if the dimensions of the tunnel are too small, single mode propagation will be established within the tunnel and, consequently, the desired field distribution will not be achieved. In order to excite multiple modes, at least one of the dimensions of the cavity is preferably at least three times as long as the interrogating signal's carrier frequency wavelength. For example, given a carrier frequency of 2.45 GHz, the carrier frequency wavelength is approximately four tenths of a foot and at least one dimension of the tunnel 108 is selected to be at least two to three feet long. Experiments conducted with a tunnel having a width W of approximately four feet, a length L of approximately four feet, and a height H of approximately three feet, and operated with a carrier frequency of 2.45 Ghz, demonstrated successful read tag-reading within the tunnel, at various speeds, regardless of the tags' orientation or location within the tunnel.

Emitters may be added to the system to improve the coverage within the tunnel. As noted above, each of the emitters may be driven by the RF transmitter in sequence at full power, or all the emitters may be driven simultaneously, with each emitter receiving a portion of the total power. Applications which involve a substantial amount of lossy materials and RF tags distributed at somewhat random locations within the various containers may benefit from an additional emitter located beneath the conveyor which emitter would function to read tags that may otherwise be shielded by lossy materials within a container. As noted above, the additional emitter may take the form of another antenna or another reflecting surface.

In practice, the dimensions of the tunnel may be determined by the space available, the size of containers which are to be "read", or other factors. In such a situation, the carrier frequency may be chosen so that for example, multiple propagation modes are established within the tunnel. Additionally, the carrier frequency of the interrogating signal may be varied in a conventional manner, through use of "frequency hopping", in order to spread the interrogating field's energy over a variety of frequencies and throughout the read zone. In addition

to regulatory restrictions and space restrictions, there are design tradeoffs in the choice of carrier frequency. Operation at higher frequencies permits the use of smaller antennas and, therefore, smaller tags, but higher frequency operation does not provide the reading range afforded by operation at lower frequencies. All these factors are taken into account when designing an RFID base station in accordance with the principles of the invention. The design may benefit, as noted above, from the application of electromagnetic simulations.

As illustrated in Figure 4, a slitted cover 132 made of a flexible material such as a rubberized fabric or plastic and coated on one surface with a conductive material to make that surface reflective at the base station carrier frequency may be added to either or both ends of the tunnel. The flexible cover would permit the free passage of containers into and out of the tunnel 108 and, at the same time, increase the quality factor and enhance the effective read zone within the tunnel.

The use of a field shaper 108 is not limited to the tunnel arrangement of Figures 2 through 4. Additional illustrative embodiments are set forth in Figures 5A and 5B. In Figure 5A a container 118 having an RF tag is supported on a conveyor 120 located above an RF emitter 106 and a field shaper 108 having a generally parabolic reflective surface is located above the emitter 106. The conveyor 120 is preferably a roller system which permits the irradiation of the container 118 through spaces between the rollers by an interrogating RF signal. The field shaper 108 and RF emitter 106 may be placed in a variety of alternative positions. For example, the field shaper 108 could be located above or to either side of the container 118, with the RF emitter 106 positioned along with or in opposition to the field shaper 108. Similarly, in Figure 5B a container 118 having an RF tag is supported on a conveyor 120 located above an RF emitter 106 and a field shaper 108 having a cornered reflective surface, that may be hinged for angular adjustments, is located beneath the emitter 106. The conveyor 120 is preferably a roller system which permits the irradiation of the container 118 through spaces between the rollers by an interrogating RF signal. As with the arrangement of Figure 5A, the field shaper 108 and RF emitter 106

may be placed in a variety of alternative positions. For example, the field shaper 108 could be located above or to either side of the container 118, with the RF emitter 106 positioned along with or in opposition to the field shaper 108.

The foregoing description of specific embodiments of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed, and many modifications and variations are possible in light of the above teachings. The conveyor may take the form of any of a number of conveying mechanisms, including, but not limited to, a belt conveyor, a roller system, or any of a number of robotic conveyors. Any of the emitters, reflecting surfaces, or field shapers may be moved relative to a tag that is to be read in order to advantageously adjust the field pattern. Additionally, the carrier frequency of the interrogating signal may be swept to alter the field pattern set up by the interrogating signal. Either side, the top, or the bottom of the illustrative tunnel embodiment may partially or totally transparent to RF energy. Other antennas, such as multimode antennas, may be employed to establish the desired interrogating RF field. The RFID system may be advantageously employed in any number of RFID systems, including automobile toll-taking, inventory control, shipping, and security screening, for example. The embodiments were chosen and described to best explain the principles of the invention and its practical application, and to thereby enable others skilled in the art to best utilize the invention. It is intended that the scope of the invention be limited only by the claims appended hereto.

What is claimed is:

CLAIMS

1. A base station system for communicating with a radio frequency (RF) transponder (tag) within a base station tag reading volume, or enclosure, comprising:

an RF signal transmitter for generating an interrogating RF signal characterized by a carrier frequency;

an RF emitter electrically coupled to the RF signal generator; and

an RF-reflective surface arranged to reflect RF signals emanating from the RF emitter to increase the effective tag reading volume of the base station system.

2. The base station system of claim 1 wherein the RF signal carrier frequency and enclosure geometry are chosen to establish a plurality of RF propagation modes within the enclosure.

3. The base station system of claim 1 wherein the carrier frequency of the RF emitter is varied over a range of frequencies.

4. The base station system of claim 1 wherein the RF emitter moves relative to the position of an RF tag being read.

5. The base station system of claim 1 wherein the reflective surface is made up of a conductive mesh the openings of which are less than one tenth the wavelength of the RF signal's carrier frequency.

6. The base station system of claim 1 wherein the reflective surface is formed of a metallic sheet

7. The base station system of claim 1 wherein the reflective surface is formed of a conductive coating attached to a non-reflective surface.

8. The base station system of claim 1 wherein the enclosure is formed of a plurality of contiguous sides of a rectilinear enclosure.

9. The base station system of claim 1 wherein the enclosure is formed of four contiguous reflective sides of a rectilinear tunnel enclosure each side at least twice the length of the wavelength of the signal produced by transmitter.

10. The base station of claim 1 wherein the enclosure is formed of a plurality of sides of a tunnel enclosure.

11. The base station system of claim 10 wherein the enclosure further comprises a flexible RF-reflective cover situated over an entrance to the tunnel enclosure.

12. The base station system of claim 1 further comprising a plurality of RF emitters.

13. The base station system of claim 1 further comprising a conveyor system for transporting RF tags into the enclosure.

14. A base station system for communication with one or more radio frequency tags, the tags to be placed at an RF tag reading location, the system comprising:

an RF emitter which transmits a direct interrogating signal having RF energy to an RF tag reading location; and

a field shaper which reflects RF energy from the RF emitter to the RF tag reading location, the field shaper being situated such that the field strength of the

superimposed reflected and direct signals meets or exceeds the field strength read threshold of an RF tag of interest.

15. The base station system of claim 14 further comprising:
an RF tag situated in the tag reading location.

16. The base station system of claim 15 further comprising:
a conveyor which conveys the tag to the tag reading location.

17. The base station system of claim 16 wherein the conveyor conveys the tag to the reading location such that the tag is irradiated by an interrogating signal which meets the tag's field strength read threshold.

18. The base station system of claim 17 wherein the tag is irradiated by such an interrogating signal continuously for a period of time that permits the tag to transmit at least one minimal data packet.

19. The base station system of claim 17 wherein the tag has a maximum period of operation without irradiation and the interrogating signal irradiates the tag intermittently to provide the tag with operational power with at least one period of intermittence being less than the tag's maximum period of operation without irradiation.

20. The base station system of claim 14 wherein the field shaper is in the form of tunnel having an RF-reflective side.

21. The base station system of claim 18 wherein the tunnel has a rectangular cross section.

22. The base station system of claim 18 wherein the tunnel has an elliptical cross section.

23. The base station system of claim 18 wherein the signal generator sweeps the carrier frequency of the interrogating RF signal to thereby vary the field strength at the tag reading location.

24. The base station system of claim 23 wherein the tag has a maximum period of operation without irradiation and the interrogating signal irradiates the tag intermittently to provide the tag with operational power, with at least one period of intermittence being less than the tag's maximum period of operation without irradiation

25. The base station system of claim 23 wherein the tag is irradiated by an interrogating signal such that minimum threshold period is met for a period of time which permits the continuous transmission of more than a single, minimum data packet.

26. The base station system of claim 14 wherein the field shaper forms a resonant cavity having a quality factor in the range of 2 to twenty.

27. The base station system of claim 14 wherein the direct and indirect interrogating signals irradiate the tag simultaneously.

28. The base station system of claim 14 wherein the direct and indirect interrogating signals irradiate the tag sequentially.

29. The base station system of claim 14 wherein the interrogating signal is elliptically polarized.

30. The base station system of claim 29 wherein the interrogating signal is circularly polarized.

31. The base station system of claim 29 wherein the interrogating signal is linearly polarized.

32. A base station system for communication with one or more radio frequency tags, the system comprising:

a radio frequency signal generator;

an enclosed volume with a cross section, a length, and a conductive boundary;

an emitter located within the enclosed volume and electrically connected to the radio frequency signal generator, the emitter producing an electromagnetic field within the enclosed volume, said field having a profile determined by one or more modes of propagation within the enclosed volume.

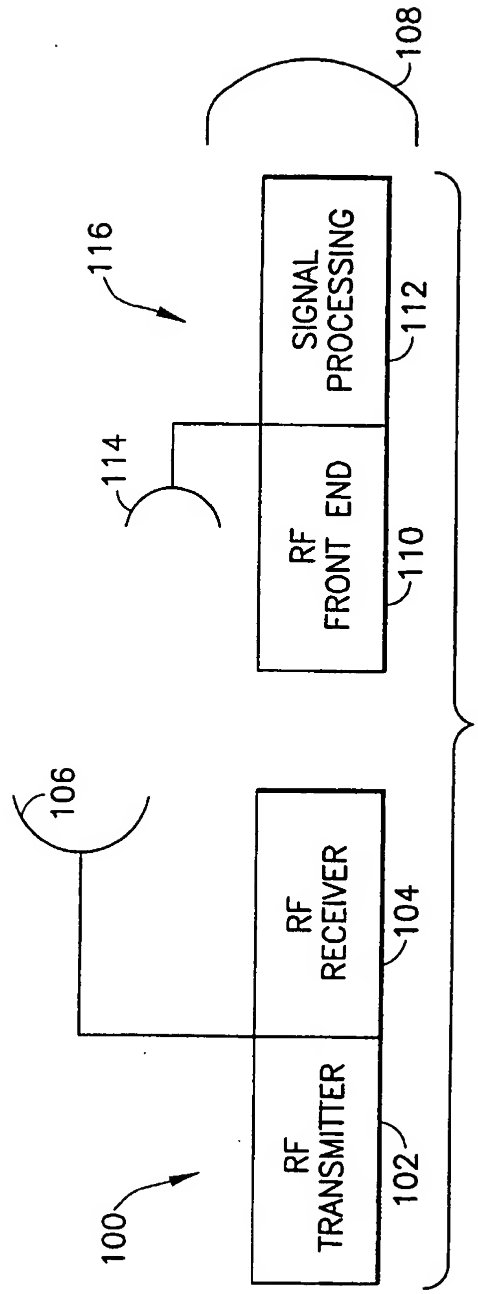

FIG.1

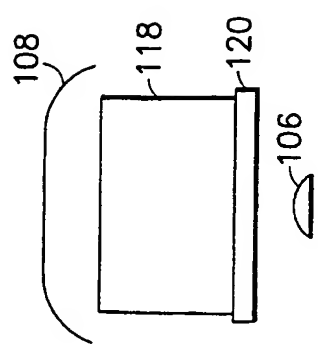

FIG.5A

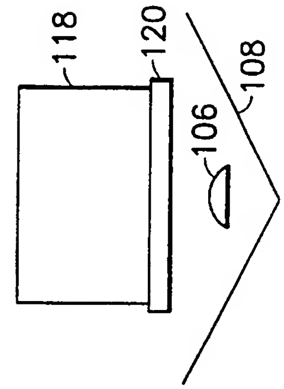

FIG.5B

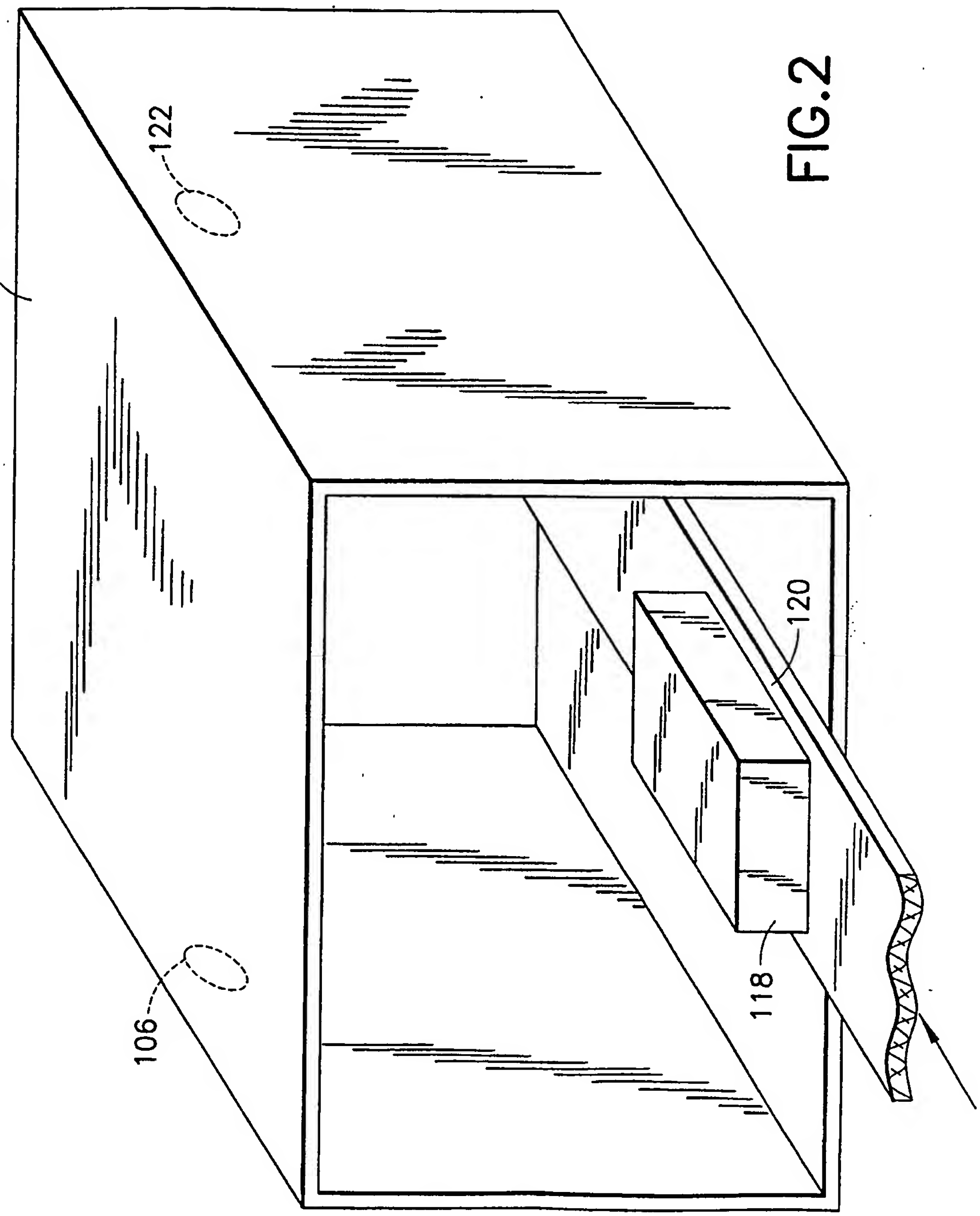

FIG.2

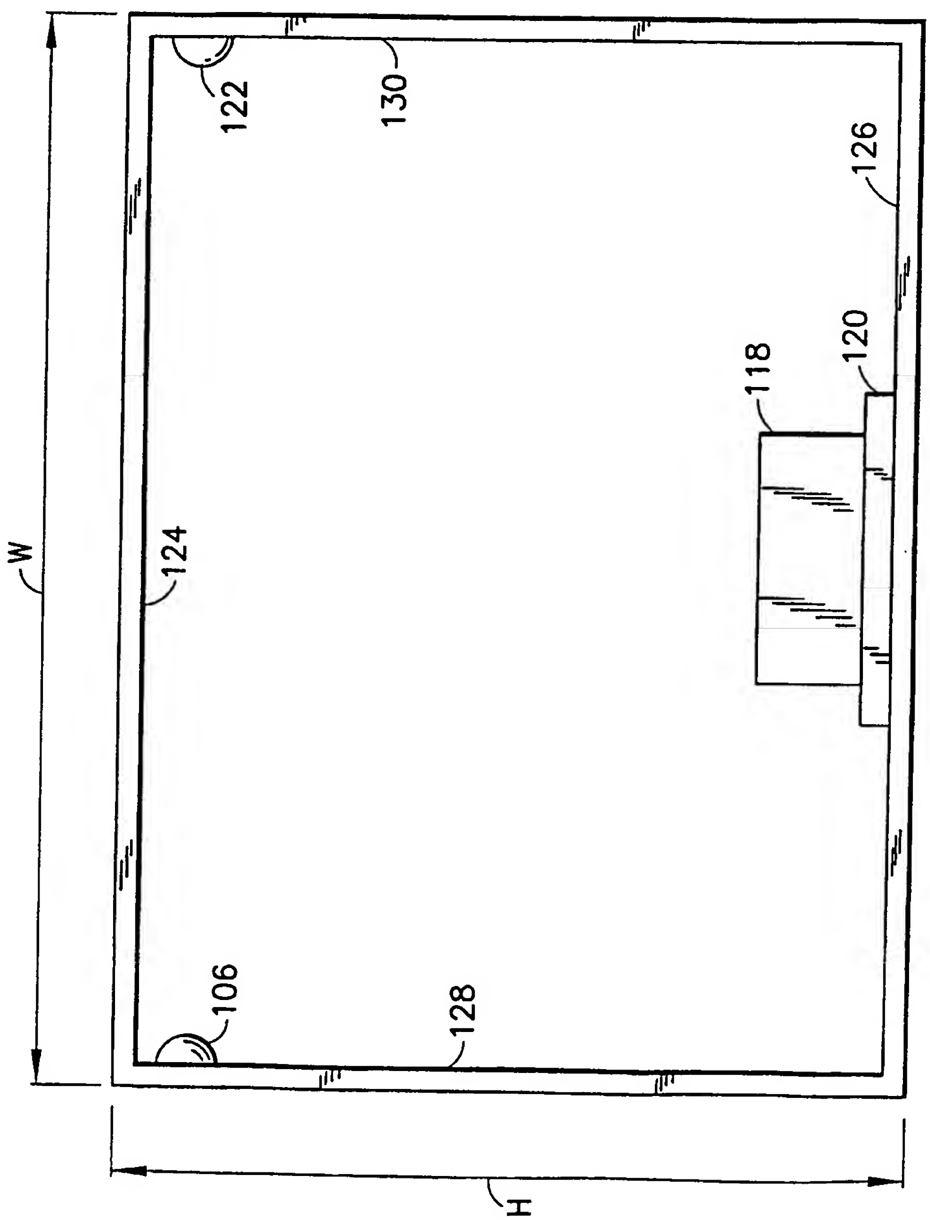

FIG.3A

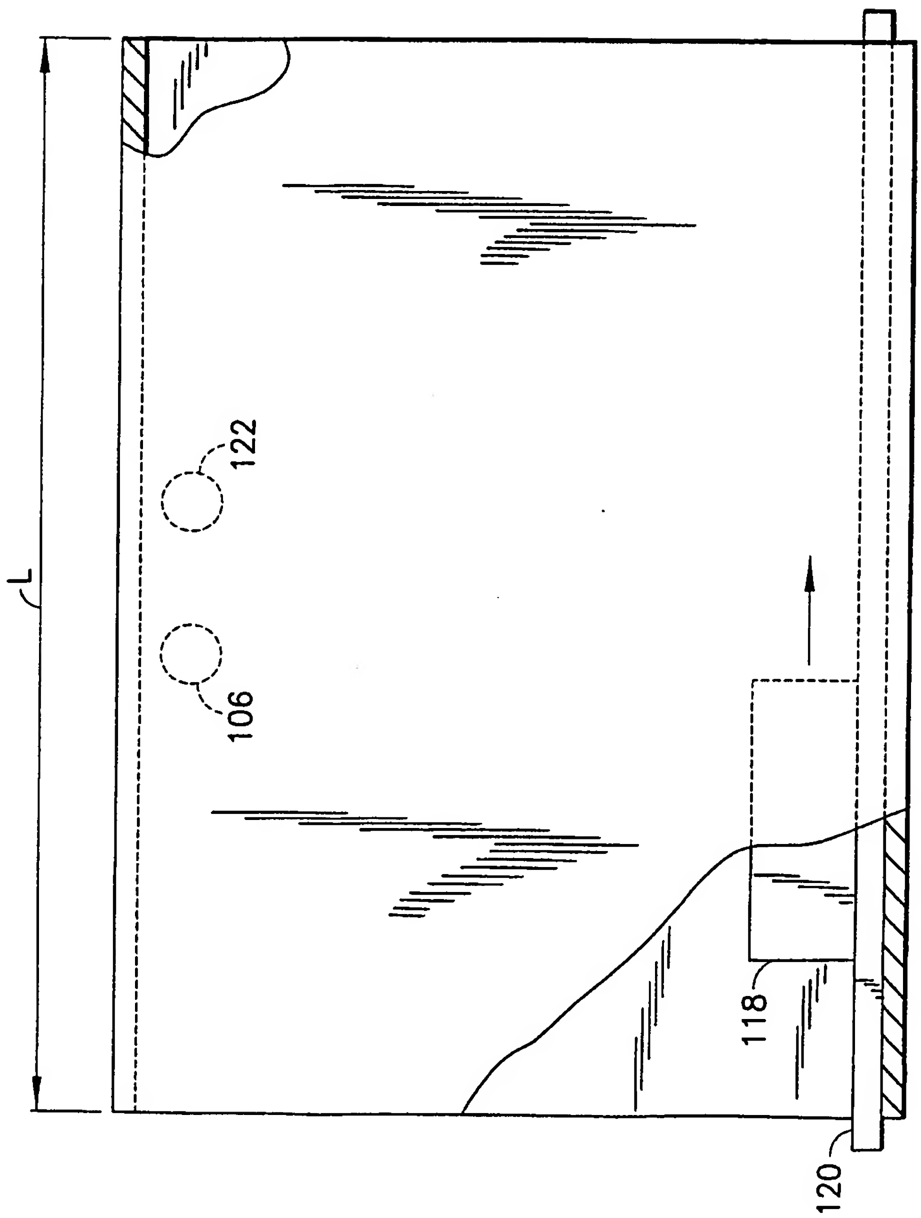

FIG.3B

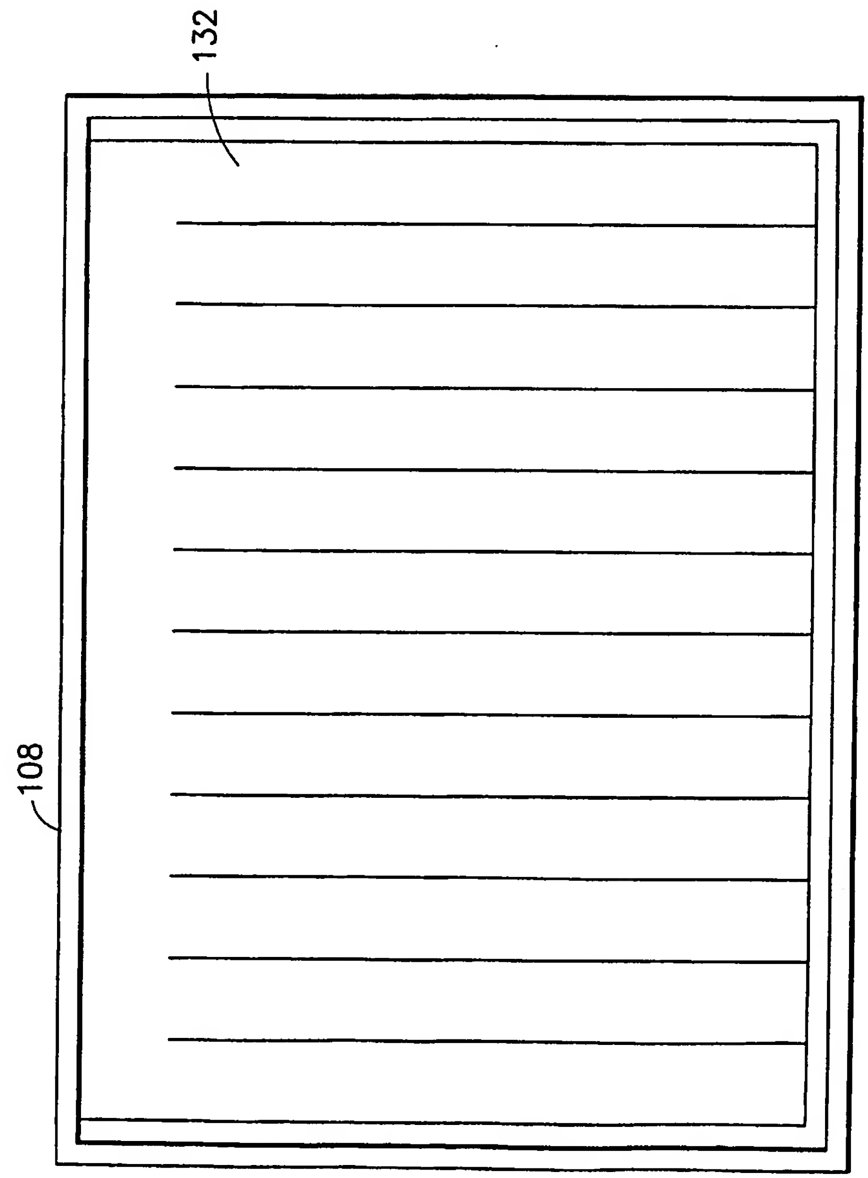

FIG.4